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Spectral Noise from Physical Vibrations

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Studies of the bending magnet synchrotron light at beamline 1.4.3 during October and November of 1997 revealed noise throughout the measured IR spectrum. For example, figure 1 displays the ratio of 128 scans at 4 cm^{-1} resolution to another 128 scans showed an RMS scatter around 100% of 0.5%. A well working FTIR system in this configuration should have RMS noise values below 0.01%. Through careful detective work, we identified the primary source of the extra noise as due to mechanical vibrations of the beamline primarily caused by large water pumps just inside the shield wall from B11.4. Several steps were taken, in conjunction with LBL engineers, which have significantly improved these vibrations and improved the measured signal to noise ratio.

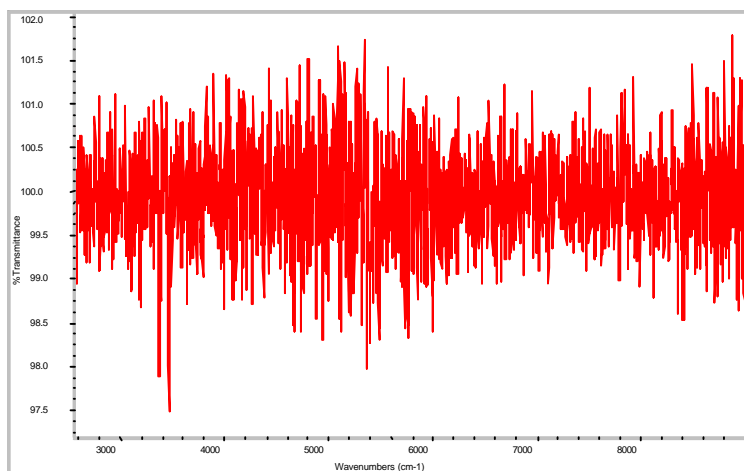


Figure 1. Noise measured October 19, 1997 showing 0.5% RMS deviation from 100% throughout the mid-IR region.

Figure 1 demonstrates the basic problem. Due to motion of the IR light beam, the measured signal to noise ratio is 0.5% RMS over the mid-IR region. This is roughly 100 times worse than desirable. The interferometer inside an FTIR spectrometer is far more sensitive to motions of the light beam than a dispersive spectral instrument due to the interference of the beam with itself. This interference will change when the beam path is varied by less than the wavelength of light, whereas motion on an overfilled slit of a grating instrument will not cause significant intensity changes.

We performed a number of tests to try to identify the source of the light motion causing this noise. Since the signal to noise was reasonably low when using the internal Globar source, we could rule out problems with the electronics and relative motion between the interferometer and detector. We subsequently looked for beam motion due to physical vibrations of the mirrors on the front end of the beamline, and also motion of the electron beam inside the storage ring. By sending our detector signal to a spectrum analyzer, the primary frequencies of this motion were measured to be around 30, 60, and 231Hz. Comparing this to acceleration data acquired by placing an accelerometer directly on the floor where the beamline is located showed a match of many of these frequencies. The dominant vibrations measured in the floor are frequencies of 29, 58, 120, and 231Hz.

A systematic study of what on the ALS experimental floor is causing these vibrations of the floor, and hence the mirrors in beamline 1.4, was undertaken. The Scroll pump on the switchyard, the air conditioning in the storage ring and in the end-station hutch, the low conductivity water (LCW) for sector 1, the air cooling of the pinger located next to the 1.4 beam port, and the water cooling of the RF cavities were each turned off and on which accelerometer data was measured. The two items that changed the measured vibrations were the LCW and the RF cavity water pumps. A closer examination of the plumbing of these two water systems showed that vibrations due to the RF cavity pumps were being coupled into the LCW water plumbing where the two systems are physically bolted together on the rear of the inner shield wall. Therefore the primary cause of vibrations was determined to be the RF cavity water cooling pumps.

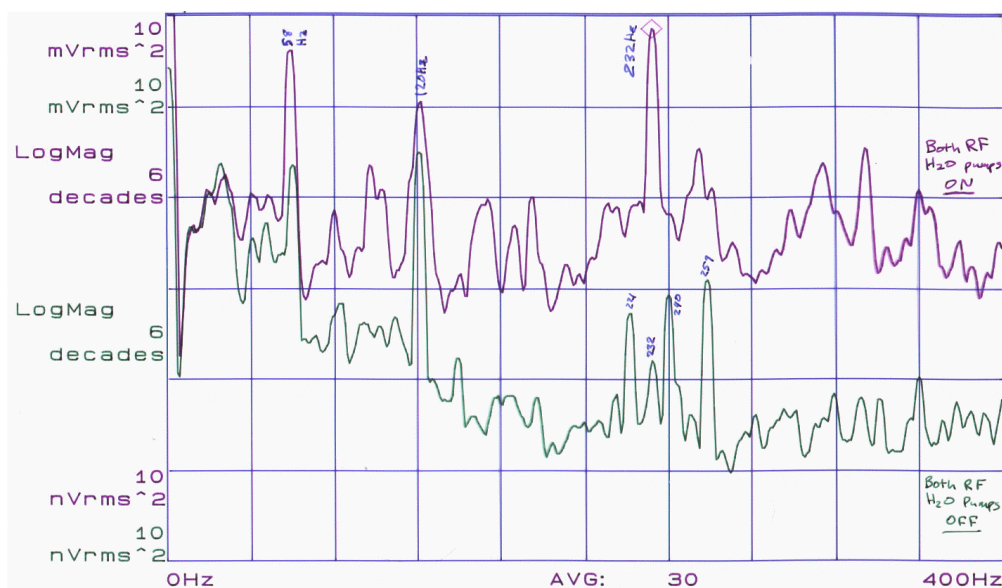


Figure 2. Accelerometer data acquired November 11, 1997 comparing the floor vibrations with the RF cavity water pumps on and off. The pumps clearly are a large source of noise at the ALS.

Figure 2 shows accelerometer data measuring the vibrations of the floor beside beamline 1.4 with the RF cavity water pumps on and off. A very significant drop in the magnitude of the vibrations is observed. A group was convened consisting of Michael Martin, Wayne McKinney, Egon Hoyer, Alan Paterson, Ted Lauritzen, Greg Portman, Bob Miller, and Jim Julian. This committee recommended both trying to reduce the source of the noise by investigating how to make the pumps quieter, and also to better isolate the BL1.4 front

end from this noisy environment. Four main actions were taken during December 1997 and January 1998:

1. Reduction of RF cavity water pump impeller diameters by 1 inch. This dropped the flow rate, which was significantly over pressurized, and therefore made the water flow less turbulent and hence quieter. These pumps remain quite noisy and continue to vibrate much more than should be on a synchrotron floor, but this was a first step in the right direction.
2. Cooling of M1 and the finger mask at the front of BL1.4 was removed from the LCW cooling, and was put on a newly purchased closed cycle chiller. Just to the touch this step made an obvious improvement to the vibrations of the front end.
3. The M1/M2 mirror chamber was bolted directly to the lower slab (the original floor in the building that we had measured to be quieter vibrationally than the upper slab). This involved drilling through the chamber stand, installing Hilti bolt sinks into the lower slab, and pumping grout between the two slabs. The upper slab was then cut around the BL1.4 front end thus freeing it from the upper slab.
4. A new support for the vacuum pipe between the M1/M2 tank and the shield wall was constructed and installed. This now allows the free motion of edge-welded bellows, which better isolate the M1/M2 tank from the vibrations on the outer shield wall.

When the beamline came back on line in March, the above four steps had indeed improved the vibrational situation. Firstly, the measured accelerometer data shows a marked decrease in the 29, 58, and 232 Hz peaks by more than an order of magnitude. Secondly, and more importantly, the signal to noise ratio measured with the IR beam improved by up to a factor of 10.

Figure 3 shows the measured noise spectra before and after these first fixes were implemented. The top curve is the same as in Figure 1, and represents the 'before' measurement. The bottom two curves show the measured signal to noise in March 1998 after the above changes were implemented. If we first only look at the spectral noise measured above $5,000 \text{ cm}^{-1}$, we see that the overall noise level has decreased from 0.5% RMS to as low as 0.05% RMS in the bottom spectra. This represents the improvement in beam stability due to the improved vibration situation.

However, as is also obvious from Figure 3, there is a new source of noise, which shows up between 1000 and 4000 cm^{-1} . This is directly converted to a beam motion in the 2 to 8 kHz region. As this is a much higher frequency than typical vibrations of physical objects, we must assume that this is a new motion of the electron beam itself. The next issue of ALS IR News will discuss what this high-frequency noise is due to, and how it is removed. As Figure 3 shows, this high-frequency noise is now the dominant problem in improving our signal to noise ratio. Once this is corrected, we plan to revisit the vibrational noise problems and once again try to minimize the vibrations

coming from the RF cavity water pumps. In the interim, some science can now be started using the BL1.4.3 spectromicroscopy beamline. By slowing down the mirror scanning speed in the FTIR bench, this high-frequency noise can be moved out of the primary range of interest to most mid-IR spectroscopists (500 – 4000 cm^{-1}). This is however just a stopgap measure; the speed of data acquisition is compromised and samples where very small signal changes need to be monitored will still have insufficient signal to noise.

To summarize, physical vibrations of our beamline primarily caused by two large water pumps used to maintain the RF cavity temperatures were observed and seriously limited the signal to noise ratio of IR measurements. One change was implemented to the pumps to somewhat reduce their vibrations, and several changes were made to better isolate the 1.4 front end from the vibrating surroundings. These were successful in reducing the vibrational noise ten-fold. However a new high-frequency noise source on the electron beam is now observed. Attacking this problem will be the topic of issue 4 of ALS IR News.

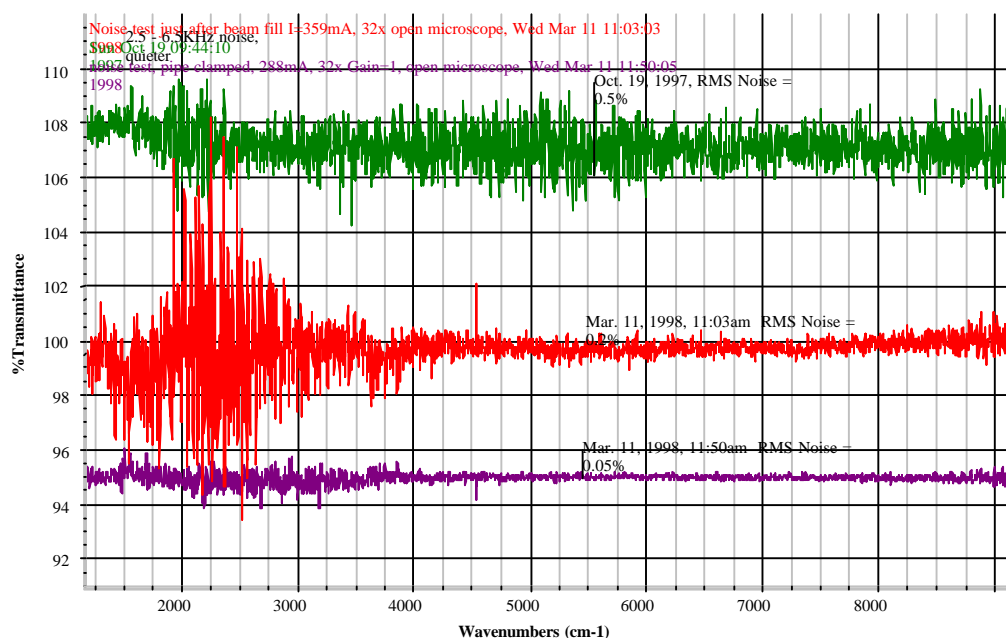


Figure 3. Comparison of noise before and after implementation of the changes described in the text. Top curve is the same as Figure 1; the bottom two spectra were obtained March 11, 1998 and demonstrate improved low-frequency vibrational noise with a new high-frequency noise source.